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RESEARCH MEMORANDUM

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Bureau of Aeronautics, Navy Department

LONGITUDINAL STABILITY AND CONTROL CHARACTERISTICS OF A

SEMISPAN MODEL OF THE XF7U-1 TAILLESS AIRPLANE AT

TRANSONIC SPEEDS BY THE NACA WING-FLOW METHOD

TED NO. NACA DE307

By

Richard H. Sawyer and James P. Trant, Jr.

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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SUMMARY

An investigation was made by the NACA wing-flow method to determine the longitudinal stability and control characteristics at transonic speeds of a semispan model of the XF7U-1 tailless airplane. The 25-percent chord line of the wing of the model was swept back 35° . The airfoil sections of the wing perpendicular to the 25-percent chord line were 12 percent thick. Measurements were made of the normal force and pitching moment through an angle-of-attack range from about -3° to 14° for several ailerator deflections at Mach numbers from 0.65 to about 1.08.

The results of the tests indicated no adverse effects of compressibility up to a Mach number of at least 0.85 at low normal-force coefficients and small ailerator deflections. Up to a Mach number of 0.85, the neutral point at low normal-force coefficients was at about 25 percent of the mean aerodynamic chord and moved rearward irregularly to 41 or 42 percent with a further increase in Mach number to about 1.05. For deflections up to -8.0° , the ailerator was effective in changing the pitching moment except at Mach numbers from 0.93 to about 1.0 where ineffectiveness or reversal was indicated for some deflections and normal-force coefficients. With -13.2° deflection at normal-force coefficients above about 0.3, reversal of ailerator effectiveness occurred at Mach numbers as low as 0.81. A nose-down trim change, which began at a Mach number of about 0.85, together with the loss in effectiveness of the ailerator, indicated that with increase in the Mach number from about 0.95 to 1.05 an abrupt ailerator movement of 5° or 6° first up and then down would be required to maintain level flight.

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INTRODUCTION

As a part of the investigation of the longitudinal stability and control characteristics of complete airplane configuration in the transonic speed range, tests have been made by the NACA wing-flow method on a 0.026-size semispan model of the XF7U-1 tailless airplane. Results of wind-tunnel tests of the same configuration up to a Mach number of 0.91 have been reported in reference 1. The present wing-flow tests covered a Mach number range of about 0.65 to 1.08. The results of normal-force, pitching-moment, and angle-of-attack measurements at various ailerator settings are presented herein for the basic configuration of the model. In order to present these results at the earliest possible date, because of the current need for aerodynamic data of this nature, a complete analysis of the results has not been made.

SYMBOLS

q	effective dynamic pressure
S	wing area of model
\bar{c}	mean aerodynamic chord of model
C_N	normal-force coefficient $\left(\frac{\text{Normal force}}{qS} \right)$
C_m	pitching moment coefficient referred to $0.17\bar{c}$ $\left(\frac{\text{Pitching moment}}{qS\bar{c}} \right)$
α	angle of attack
δ_a	deflection of ailerator (measured in plane normal to Y-axis of model) (minus sign indicates upward deflection)
M	effective Mach number
$\frac{dC_N}{d\alpha}$	slope of normal-force curve per degree
g	acceleration of gravity
R	Reynolds number
$\frac{dC_m}{dC_N}$	slope of pitching-moment curve

APPARATUS AND TESTS

The tests were made by the NACA wing-flow method (references 2 and 3) in which the model is mounted in the high-speed flow over the wing of a P-51D airplane.

Photographs of the 0.026-scale model equipped with an end plate at the fuselage center line are given as figures 1 and 2. A detailed three-view drawing is shown as figure 3. The geometric characteristics of the model are given in table I which also includes the dimensions of the full-scale airplane for comparison. The model was equipped with five interchangeable ailerators having fixed deflections of 0° , -1.6° , -4.9° , -8.0° , and -13.2° measured in a plane normal to the Y-axis of the model. The model was mounted on a shank which passed through a slot in the airplane wing and was supported on a strain-gage balance. The model and balance were arranged to rotate as a unit and, therefore, the balance measured the force normal to the chord of the model at all angles of attack. A free-floating vane, shown in figure 2, was used to determine the direction of air flow at the model location.

The chordwise and vertical gradients of velocity over the P-51D airplane wing in the region of the model were similar to those of the tests of reference 4. The effective dynamic pressure and the effective Mach number M were determined by integrating the velocity distribution over the area covered by the wing of the model.

Tests were made with each of the ailerators installed on the model in two high-speed dives of the P-51D airplane, one from a high altitude and the other from a medium altitude, and in a low-altitude high-speed level-flight run. The average relation between Mach number and Reynolds number for the tests at the various altitudes is shown in figure 4.

RESULTS AND DISCUSSION

The results of the investigation are presented in figures 5 to 14. The variation of pitching-moment coefficient and angle of attack with Mach number for normal-force coefficients ranging from -0.2 to 0.4 or 0.5 in 0.1 increments are given in figures 5 and 6, respectively, for the various ailerator deflections. The faired curves of figures 5 and 6 represent averages of the data obtained at the three altitudes. There was no effect of Reynolds

number within experimental error, as is illustrated by the sample data of figure 7. The results of figure 5 show that, at low positive normal-force coefficients and small ailerator settings, a considerable nose-down trim change occurred starting at a Mach number of about 0.85. With increasing normal-force coefficient up to about 0.4, the trim change occurred at lower Mach numbers and became more severe. The data of figure 6 indicate, in general, only moderate variations of the angle of attack at constant normal-force coefficient over the Mach number range. It will be noted that at a Mach number of about 1.0 the angle of attack for a given normal-force coefficient is approximately the same for ailerator deflections up to -8.0° , indicating ineffectiveness of the ailerator over this deflection range.

The variation of normal-force coefficient with angle of attack for each ailerator deflection shown in figure 8 for several Mach numbers is linear, at least up to a normal-force coefficient of 0.4 at all Mach numbers except for the range from 0.92 to 0.98 for which the variation is linear to somewhat smaller normal-force coefficients. The slope of the normal-force curve $dC_N/d\alpha$ (taken over the linear portion of the curve) presented in figure 9, shows a fairly gradual increase with Mach number for all ailerator deflections with no large abrupt changes indicated.

The variation of pitching-moment coefficient with normal-force coefficient at several Mach numbers for the various ailerator deflections is presented in figure 10. The slope of the pitching-moment curve dC_m/dC_N is plotted in figure 11 against Mach number for the various ailerator deflections. This slope was taken over a range of normal-force coefficients corresponding to about 1 g from the normal-force coefficient (also shown in fig. 11) required for level flight at 30,000 feet altitude with a wing loading of 28. The results of figures 10 and 11 indicate no movement of the neutral point in this normal-force-coefficient range up to a Mach number of about 0.85. At Mach numbers from 0.65 to about 0.85, the margin between the center of gravity and the neutral point for center of gravity at 0.17-percent mean aerodynamic chord was 7- to 8-percent mean aerodynamic chord and increased to 24- to 25-percent mean aerodynamic chord with increase in Mach number to 1.05. This latter movement of the neutral point was progressively rearward for ailerator deflections from -4.9° to -13.2° ; but for ailerator deflections of 0° and -1.6° , the movement was first rearward, then forward, and finally rearward.

The results of figure 5 have been rearranged in figure 12 to show the variation of pitching-moment coefficient with Mach number for each ailerator deflection at constant normal-force coefficient.

Figure 13 gives the variation of pitching-moment coefficient with ailerator deflection for various normal-force coefficients at several Mach numbers. The results of figures 12 and 13 indicate that for ailerator deflections up to -8.0° , the ailerator is effective in changing the pitching moment at Mach numbers up to about 0.93 and above about 1.0. At Mach numbers from about 0.94 to 1.0 ailerator ineffectiveness or reversal is indicated for some deflections and normal-force coefficients. With -13.2° deflection at normal-force coefficients above about 0.3, reversal of ailerator effectiveness occurs at Mach numbers as low as 0.81.

The ailerator deflections required to trim the full-scale airplane in level and 2g accelerated flight at Mach numbers from 0.65 to 1.08, as determined from the results of figure 5, are given in figure 14. The wing loading was taken as 28, the center of gravity at 17-percent mean aerodynamic chord, and the altitude as 30,000 feet. The normal-force coefficients required for level and 2g accelerated flight are also shown. The cross-hatched area indicates a range of Mach numbers for which the airplane apparently could be trimmed at two or three ailerator deflections as the result of reversal of ailerator effectiveness at these Mach numbers. For level flight the results indicate a slight decrease in ailerator deflection with increase in speed up to a Mach number of about 0.85. At Mach numbers increasing from 0.85 to 0.95 an up-ailerator movement of about 2° is indicated. With further increase in Mach number from 0.95 to 1.05 an abrupt ailerator movement of 5° or 6° , first up and then down, would be required. In order to attain a 2g acceleration from the level-flight condition, an up-ailerator movement of from 1° to as much as 11° , depending on the Mach number, would be required in the Mach number range from 0.90 to 1.05.

CONCLUDING REMARKS

The results of NACA wing-flow tests of the longitudinal stability and control characteristics of a semispan model of the XF7U-1 airplane throughout the Mach number range from 0.65 to 1.08 indicated no adverse effects of compressibility up to a Mach number of at least 0.85 at low normal-force coefficients and small ailerator deflections. Up to a Mach number of 0.85, the neutral point at low normal-force coefficients was at about 25 percent of the mean aerodynamic chord and moved rearward irregularly to 41 or 42 percent with further increase in Mach number to about 1.05. For deflections up to -8.0° , the ailerator was effective in changing the pitching moment except at Mach numbers from 0.93 to 1.0 where ineffectiveness

or reversal was indicated for some deflections and normal-force coefficients. With -13.2° deflection at normal-force coefficients above about 0.3, reversal of ailerator effectiveness occurred at Mach numbers as low as 0.81. A nose-down trim change which began at a Mach number of about 0.85, together with the loss in effectiveness of the ailerator, indicated that with increase in the Mach number from about 0.95 to 1.05, an abrupt ailerator movement of 5° or 6° first up and then down would be required to maintain level flight.

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ESY

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1. Kemp, William B., Jr., Kuhn, Richard E., and Goodson, Kenneth W.: An Investigation of the Aerodynamic Characteristics of an 0.08-Scale Model of the Chance Vought XF7U-1 Airplane in the Langley High-Speed 7- by 10-Foot Tunnel. Part I - Basic Longitudinal Stability Characteristics. TED No. NACA DE308. NACA RM No. L7G08, Bur. Aero., 1947.
2. Gilruth, R. R., and Wetmore, J. W.: Preliminary Tests of Several Airfoil Models in the Transonic Speed Range. NACA ACR No. L5E08, 1945.
3. Zaloveik, John A., and Adams, Richard E.: Preliminary Tests at Transonic Speeds of a Model of a Constant-Chord Wing with a Sweepback of 45° and an NACA 65(112)-210, $a = 1.0$ Airfoil Section. NACA ACR No. L5J16a, 1945.
4. Johnson, Harold I.: Measurements of Aerodynamic Characteristics of a 35° Sweptback NACA 65-009 Airfoil Model with $1/4$ -Chord Plain Flap by the NACA Wing-Flow Method. NACA RM No. L7F13, 1947.

TABLE I

GEOMETRIC CHARACTERISTICS OF MODEL
AND OF FULL-SCALE AIRPLANE

	Model	Full-scale airplane
Wing: Section (perpendicular to 25-percent chord line) Semispan Mean aerodynamic chord Chord at tip Chord at plane of symmetry Area (semispan) Taper ratio Aspect ratio Sweepback (25-percent chord line) Incidence (constant) Dihedral	CVA4-(00)-(12)(40)-(1.1)(1.0) 6.03 in. 4.08 in. 3.02 in. 4.99 in. 24.2 sq in. 0.605 3.01 35° 0° 0°	CVA4-(00)-(12)(40)-(1.1)(1.0) 19 ft 4 in. 13 ft 1 in. 9 ft 8 in. 16 ft 0 in. 248 sq ft 0.605 3.01 35° 0° 0°
Ailavator: Semispan Chord (parallel to plane of symmetry) Area (one) Sweepback	2.94 in. 0.91 in. 2.68 sq in. 24.5°	9 ft 5 in. 35 in. 27.5 sq ft 24.5°
Vertical tail: Area of one (including wing intersection area) Aspect ratio Sweepback (25-percent chord line)	6.24 sq in. 1.75 40°	64 sq ft 1.75 40°
Fuselage: Area of maximum cross section (1/2 fuselage) Area of engine bulge (one) Over-all length	0.792 sq in. 0.340 sq in. 11.54 in.	8.14 sq ft 3.49 sq ft 37 ft
Air ducts: Area of entrance (one) Area of exit (one)	0.156 sq in. 0.134 sq in.	1.60 sq ft 1.38 sq ft
Location of center of gravity	17 percent M.A.C.	17 percent M.A.C.

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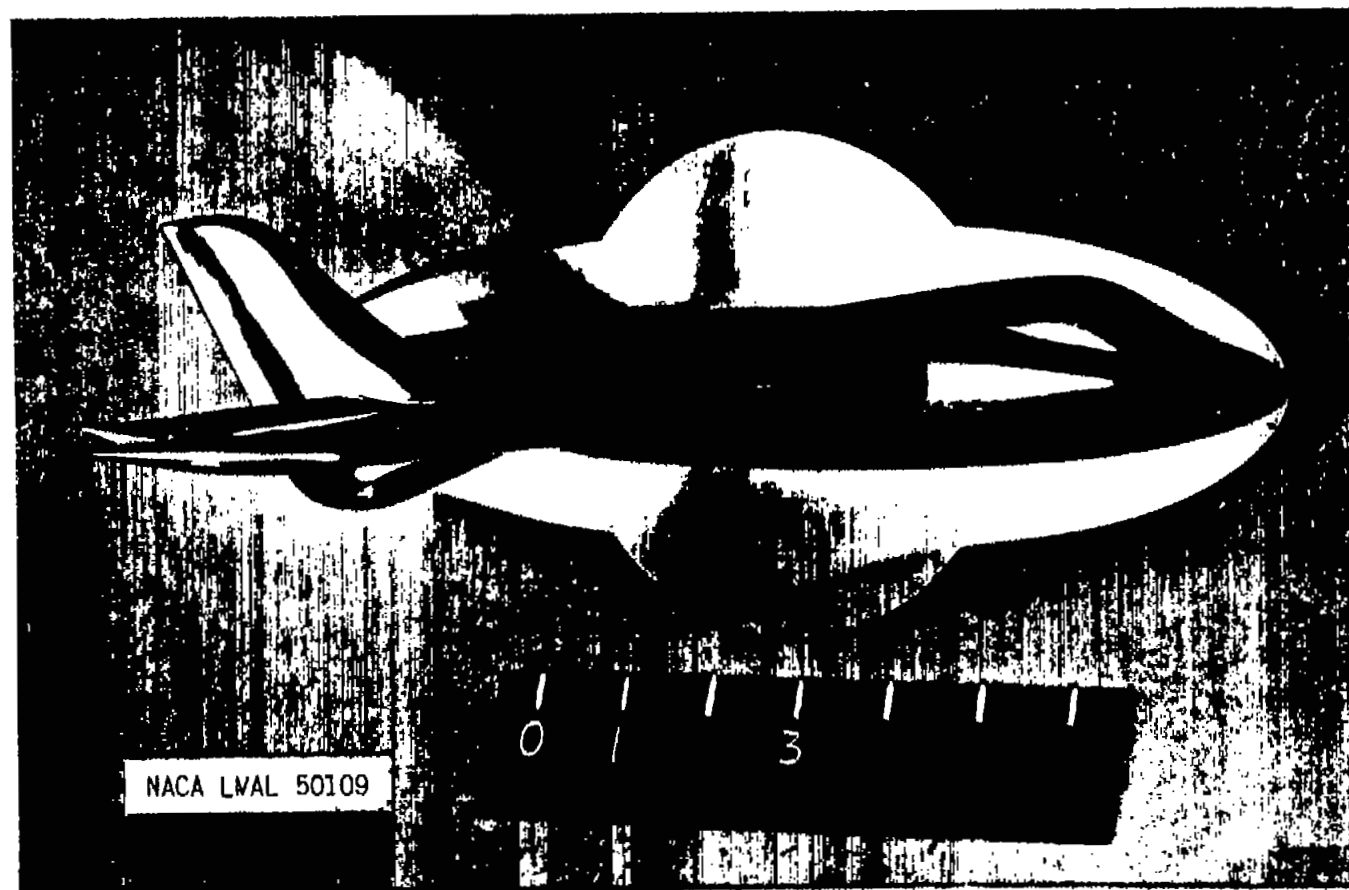


Figure 1.- XF7U-1 semispan model.

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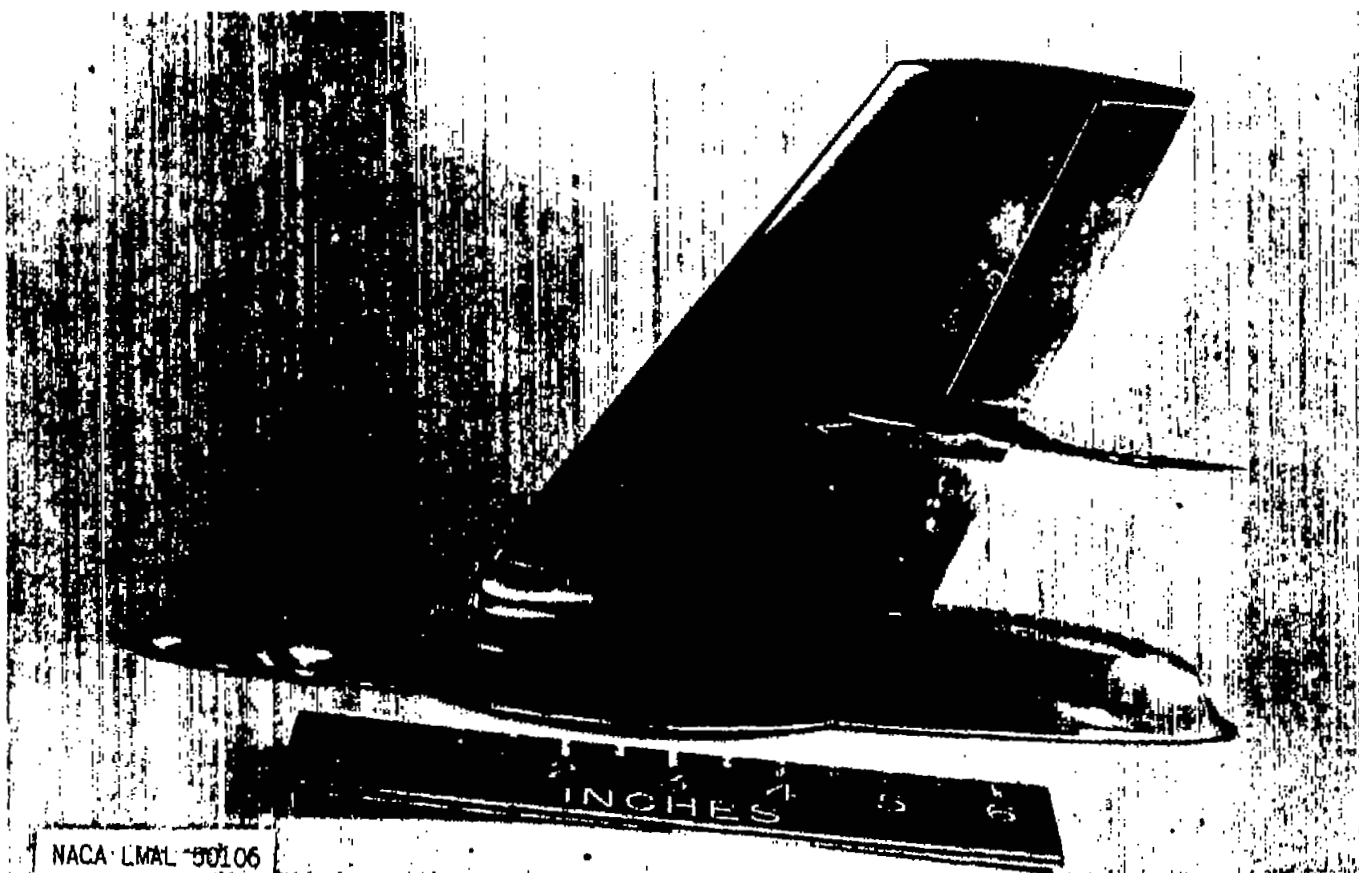


Figure 1.- Concluded.

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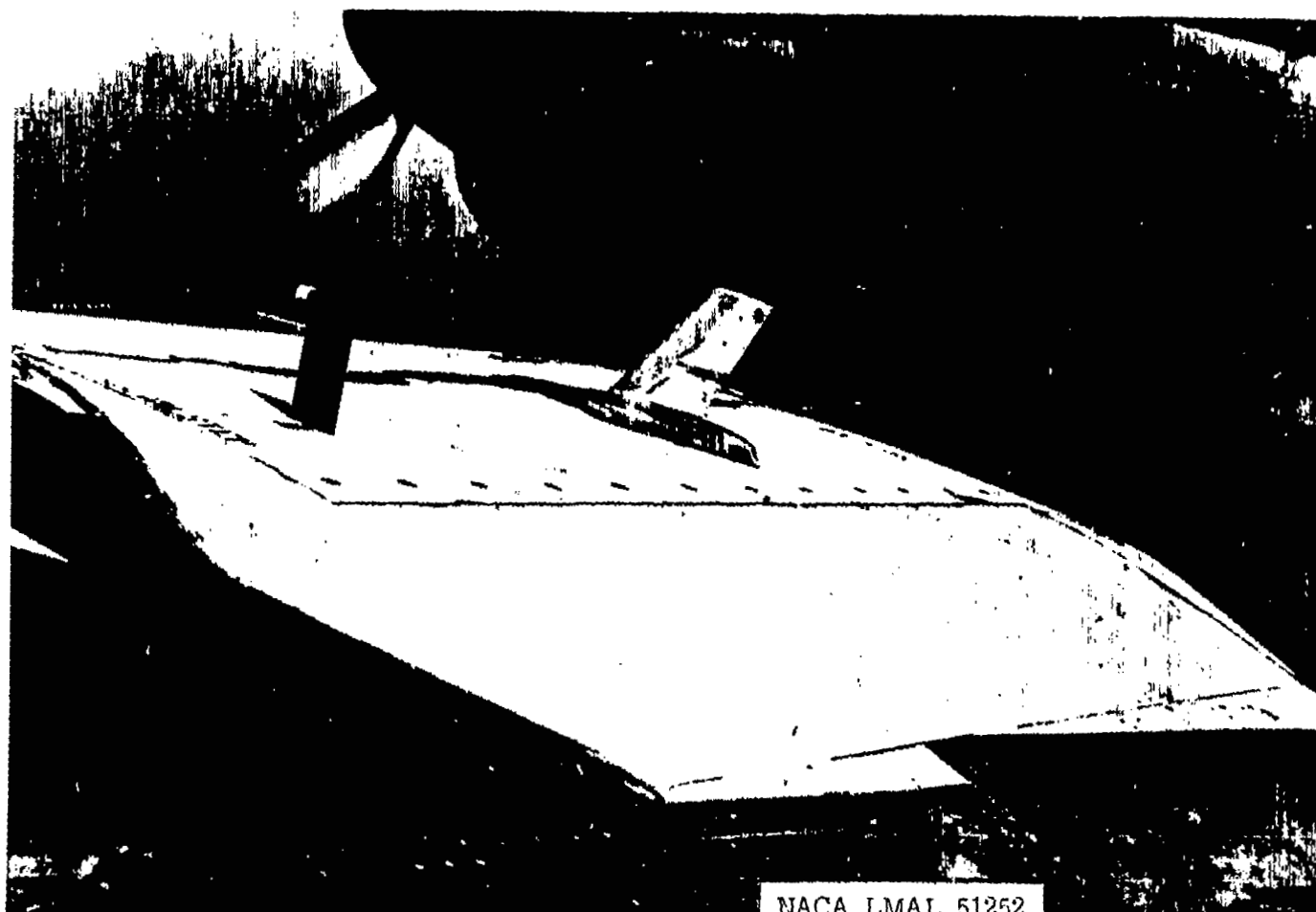
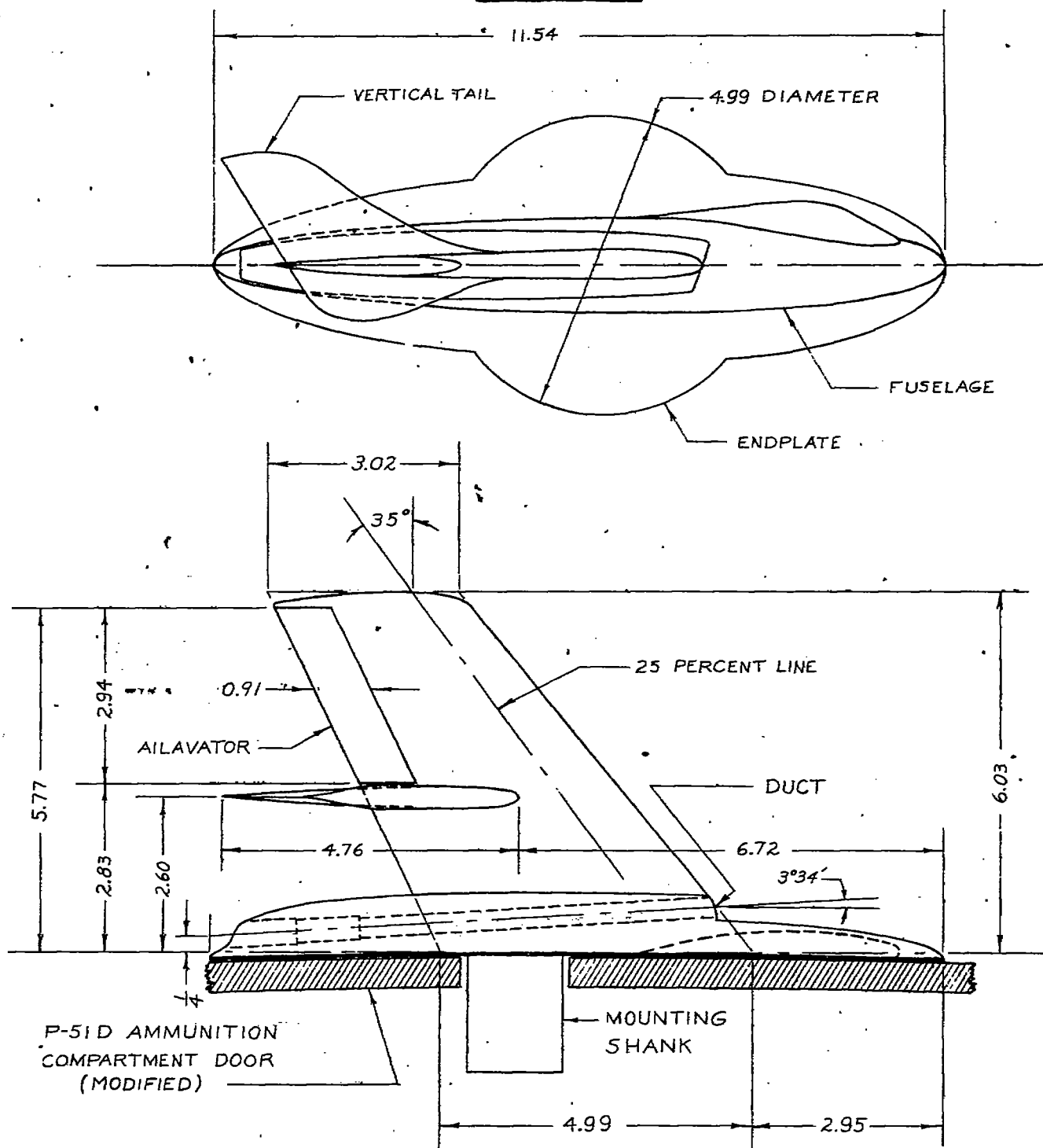


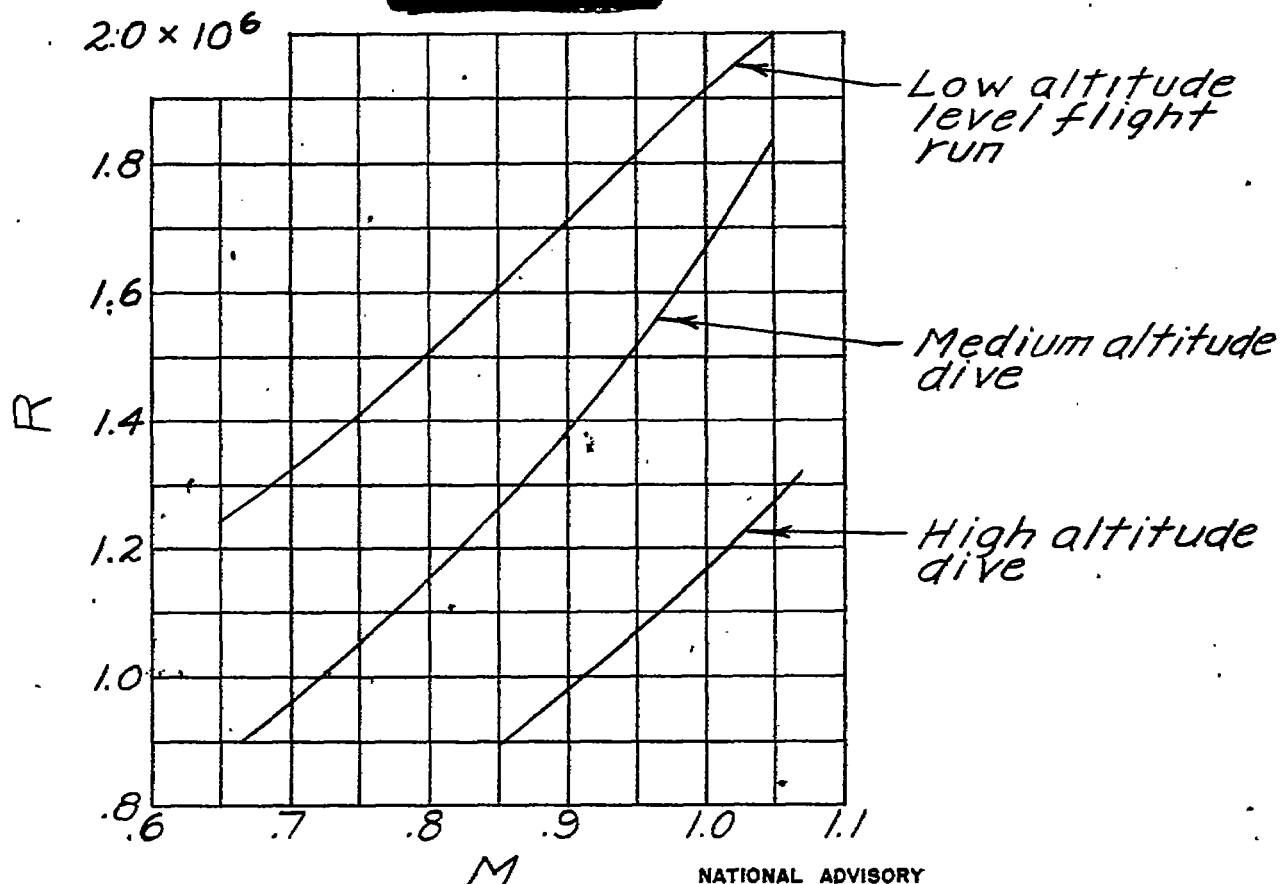
Figure 2.- XF7U-1 semispan model mounted above wing of P-51D airplane.
Free-floating vane also shown.

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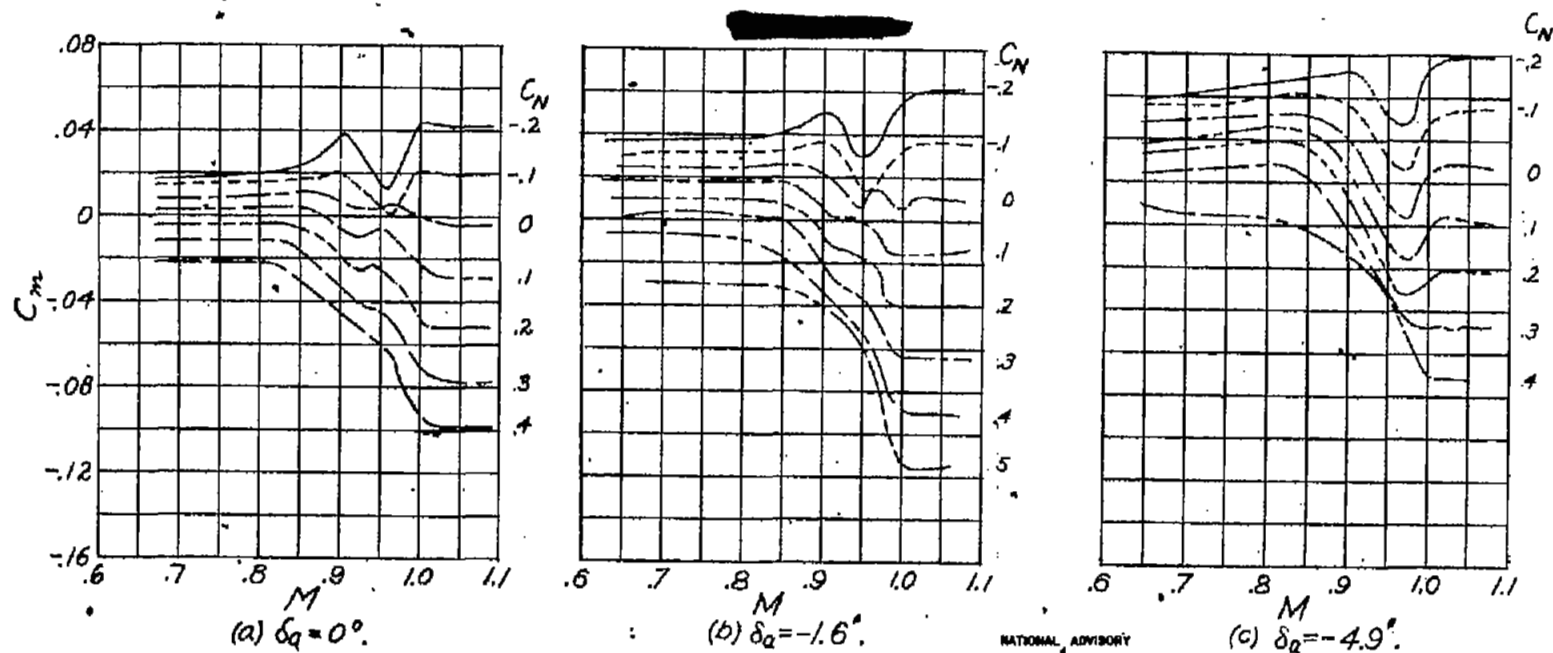
FIGURE 3.- DETAILS OF SEMISPAN XF7U-1 MODEL. ALL DIMENSIONS ARE IN INCHES.



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Figure 4.- Variation of Reynolds number with Mach number for tests in high altitude and medium altitude dives and in low altitude level flight run.

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Figure 5.- Variation with Mach number of pitching-moment coefficient at several normal-force coefficients for various ailerator deflections.

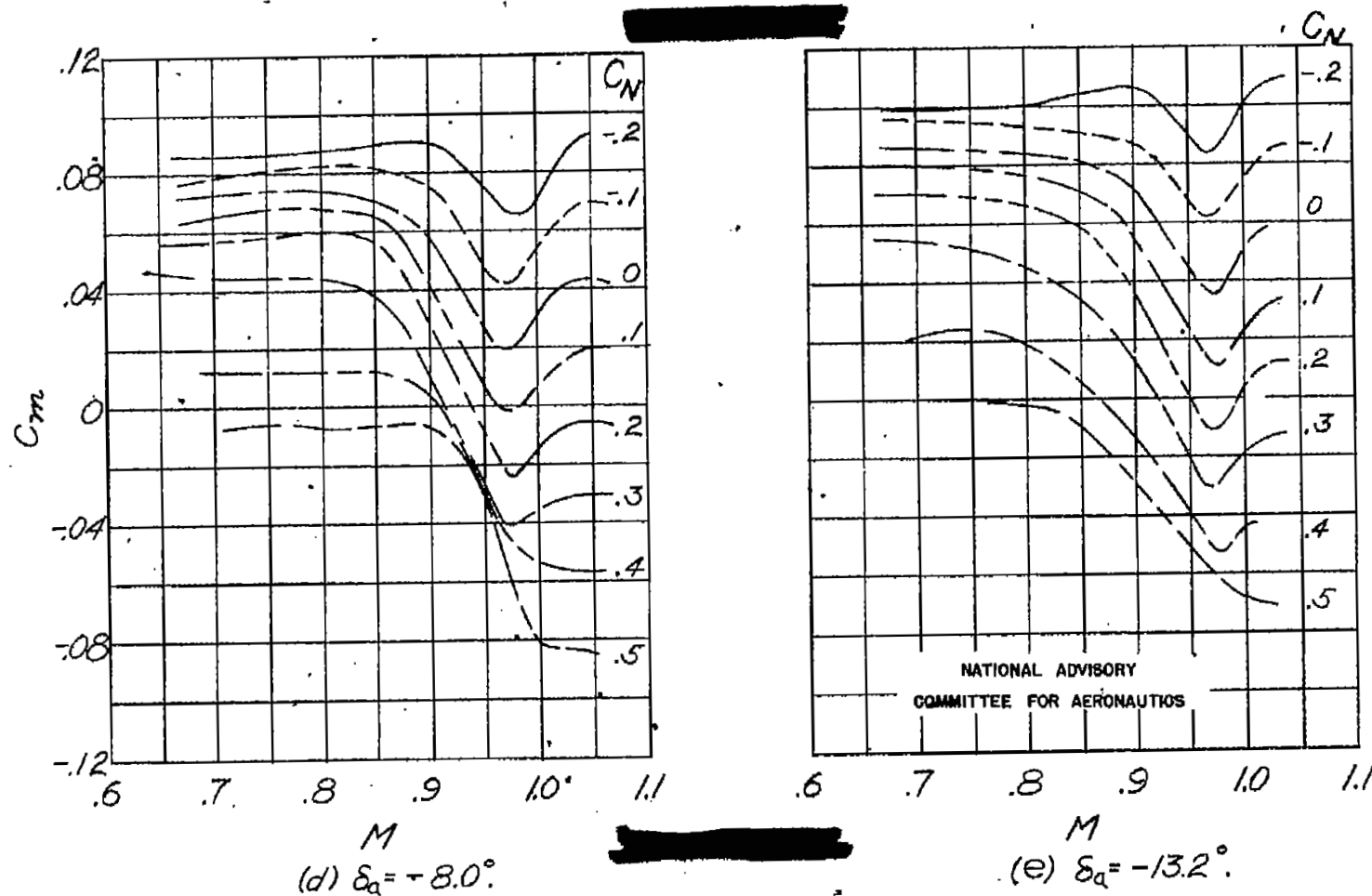


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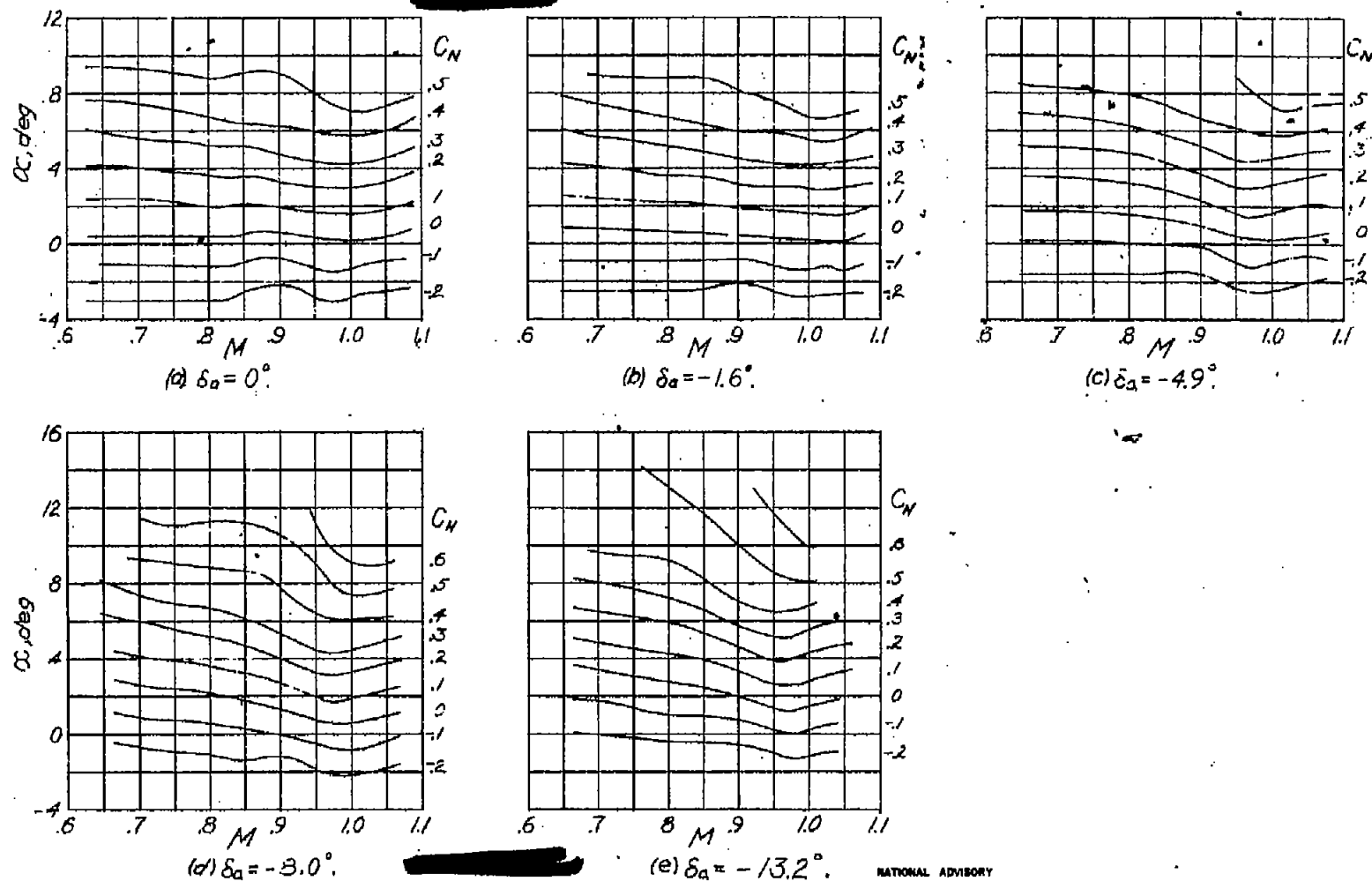


Figure 6.- Variation with Mach number of angle of attack for several normal-force coefficients at various aileron deflections.

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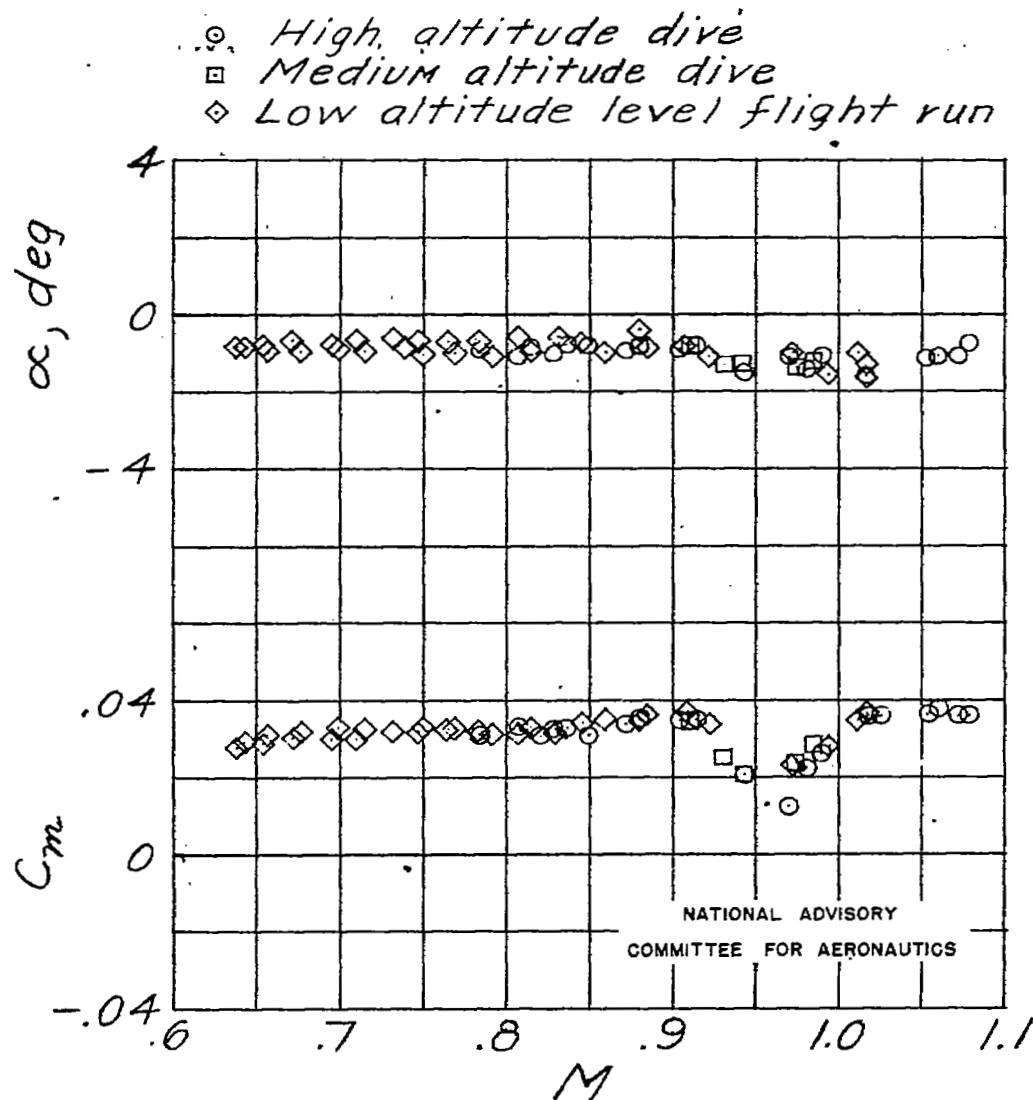


Figure 7.- Typical example of data as obtained in tests at three altitudes. $\delta a = -1.6^\circ$, $C_N = -0.1$.

[REDACTED]

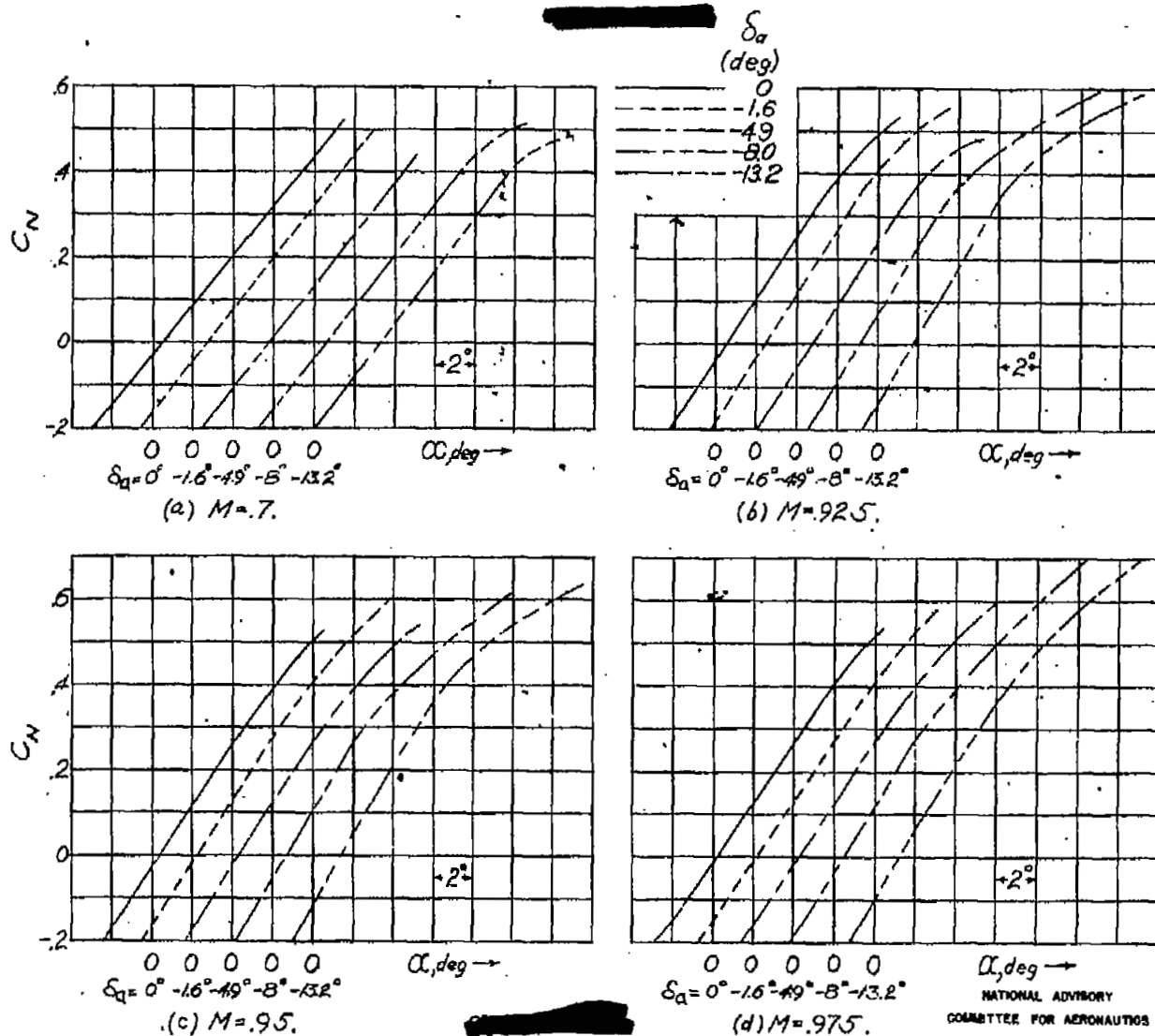
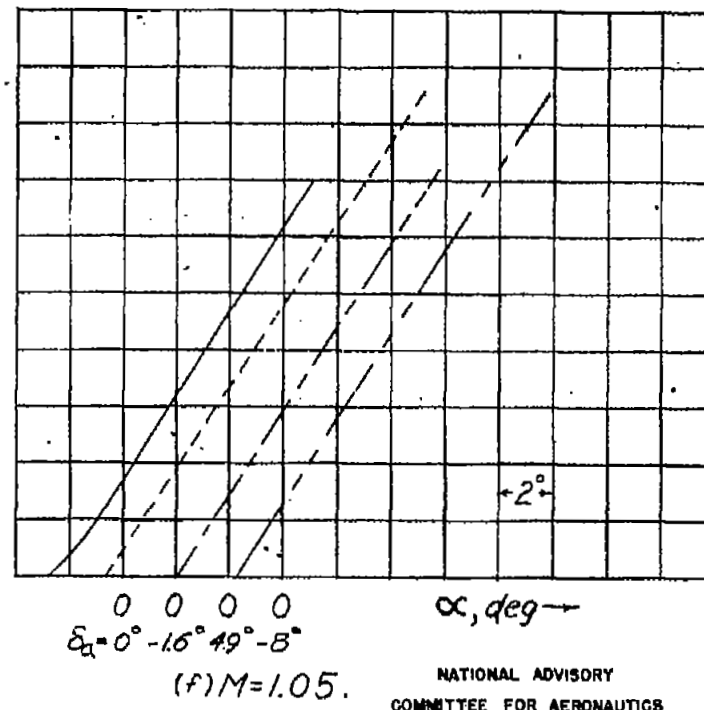
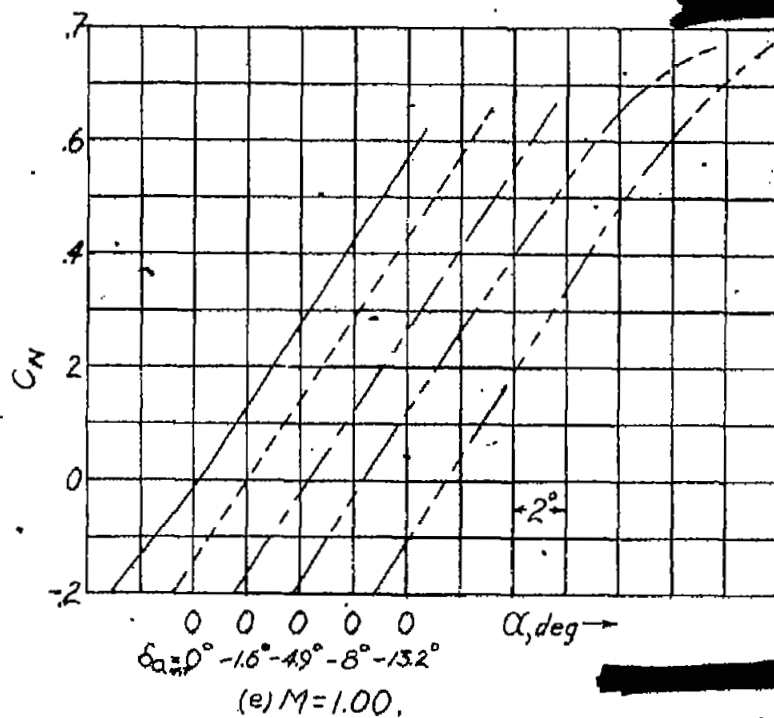


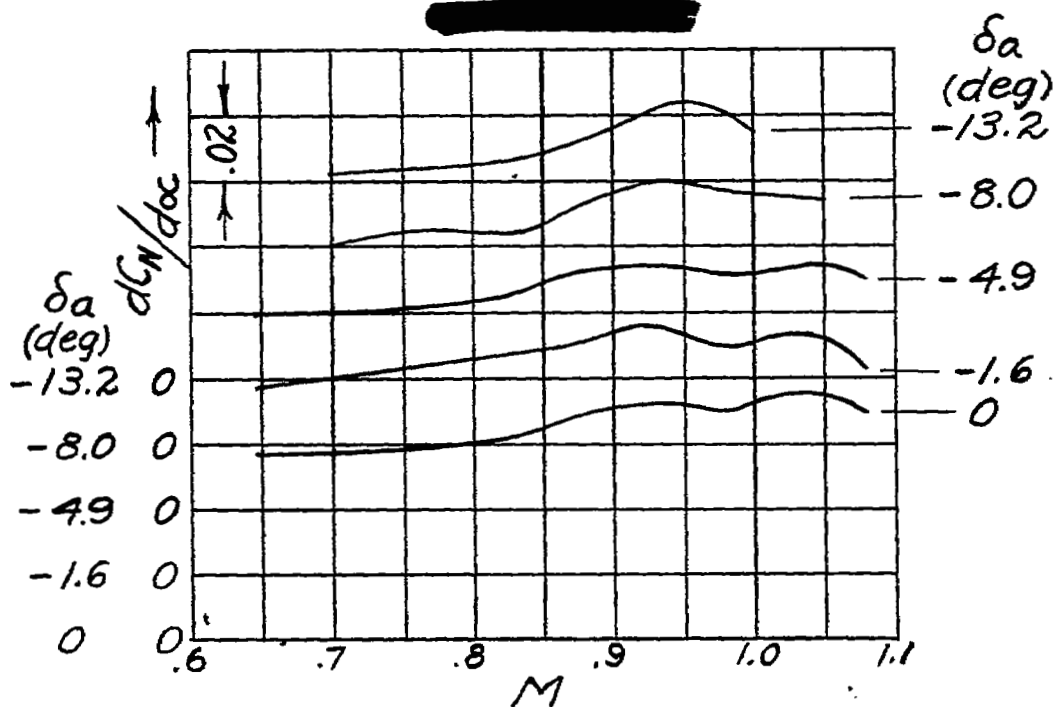
Figure 8.- Variation of normal-force coefficient with angle of attack for several ailerator deflections at various Mach numbers.

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Figure 8.- Concluded.



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Figure 9.- Variation with Mach number of slope of normal-force curve for several airfoil deflections.

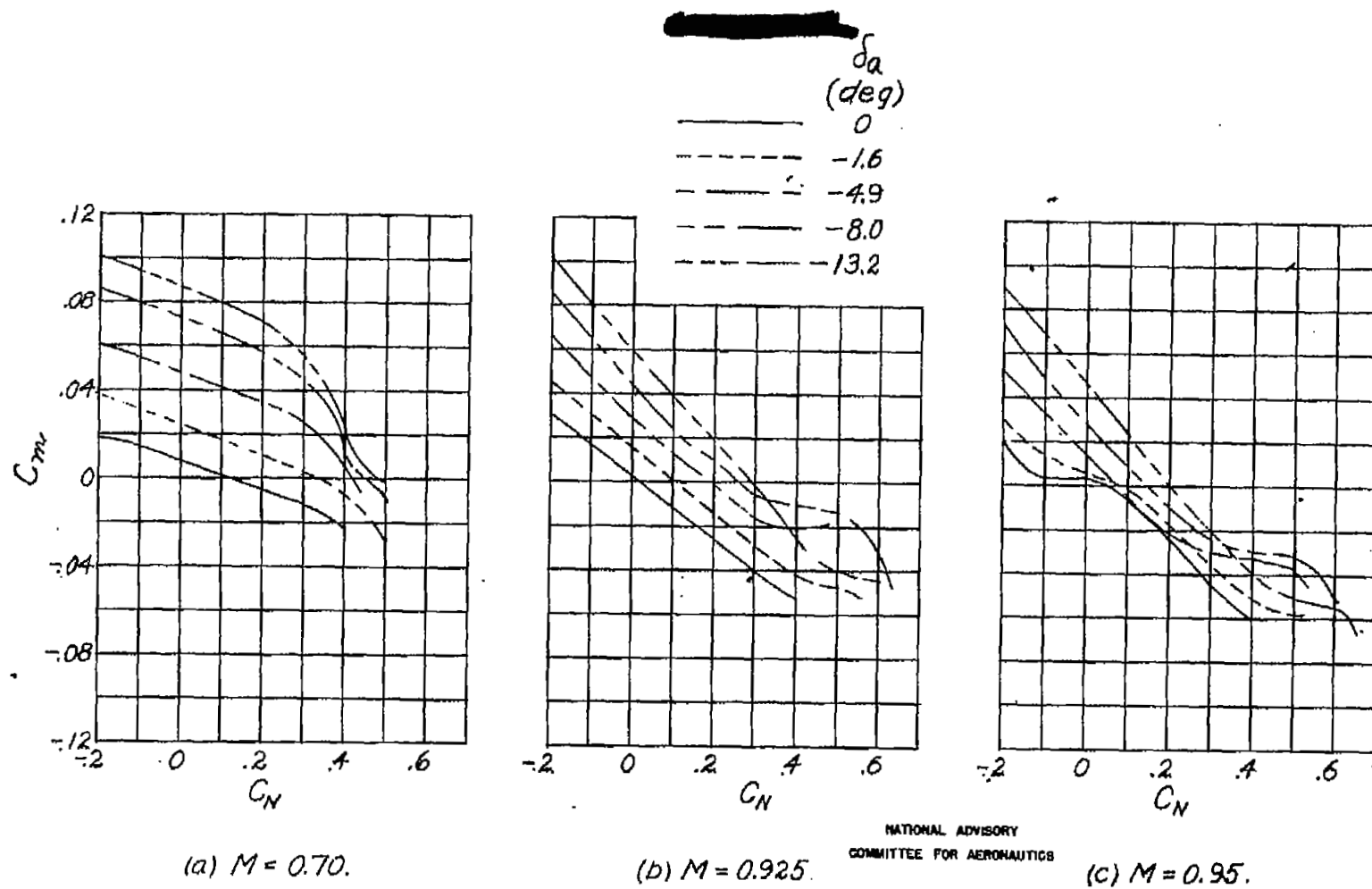


Figure 10.- Variation of pitching-moment coefficient with normal-force coefficient for various ailerator deflections at several Mach numbers.

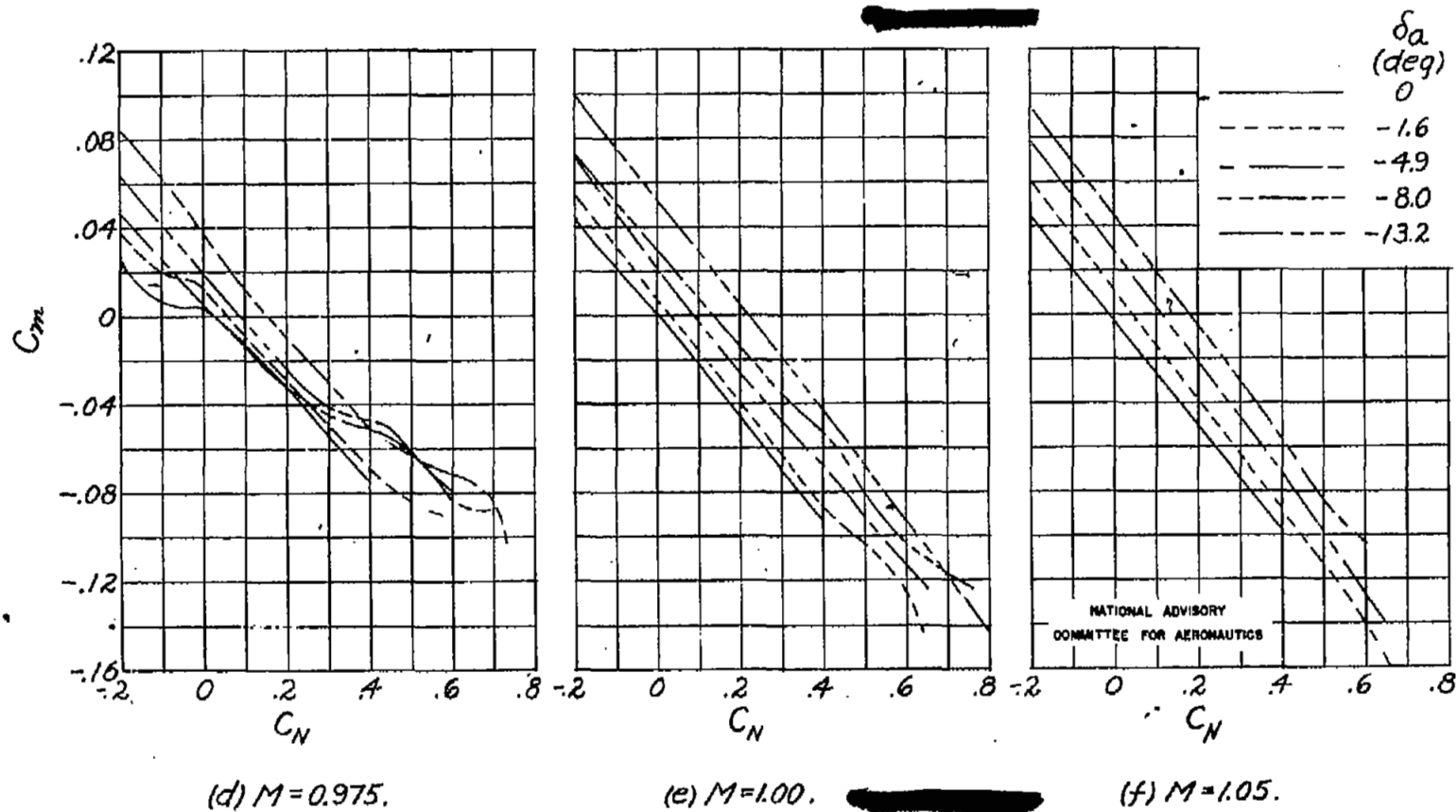


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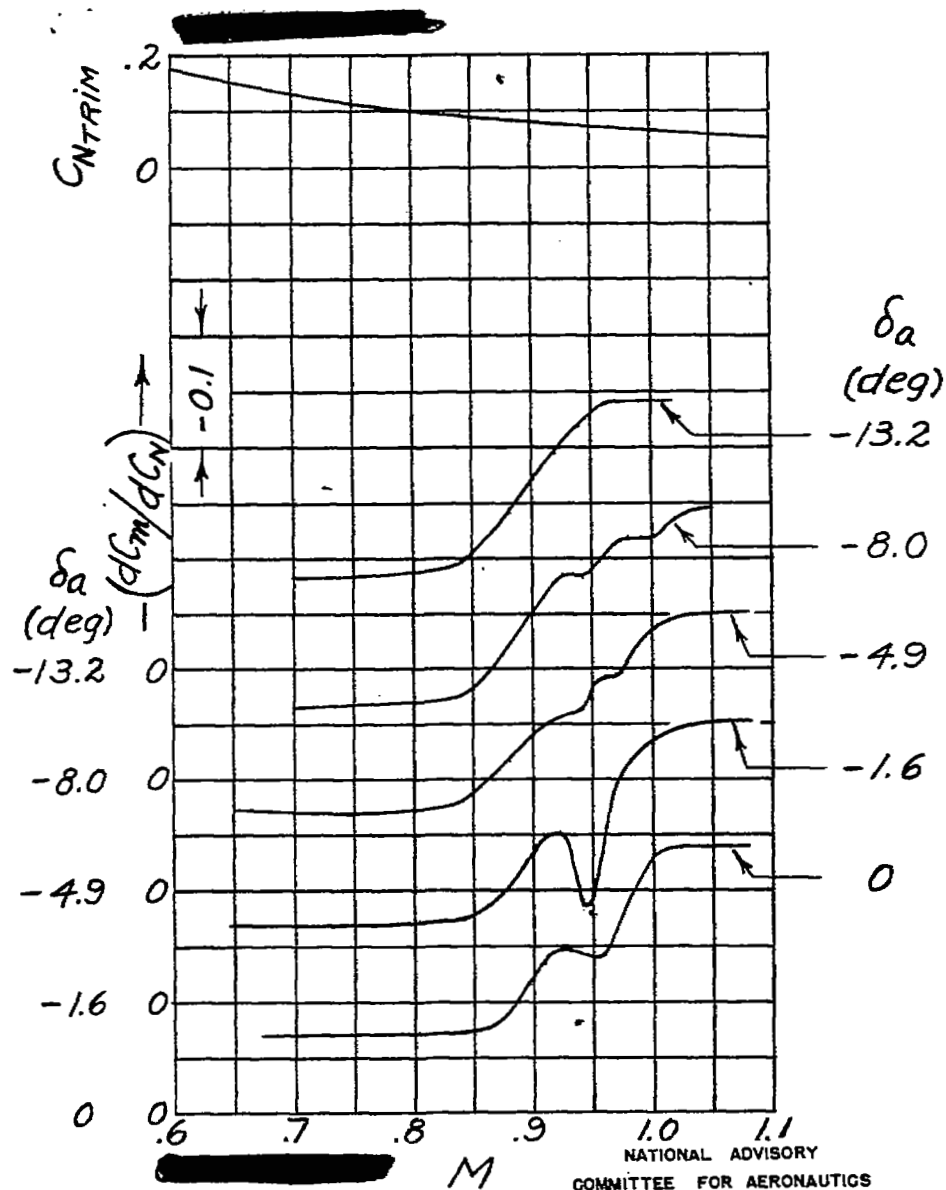
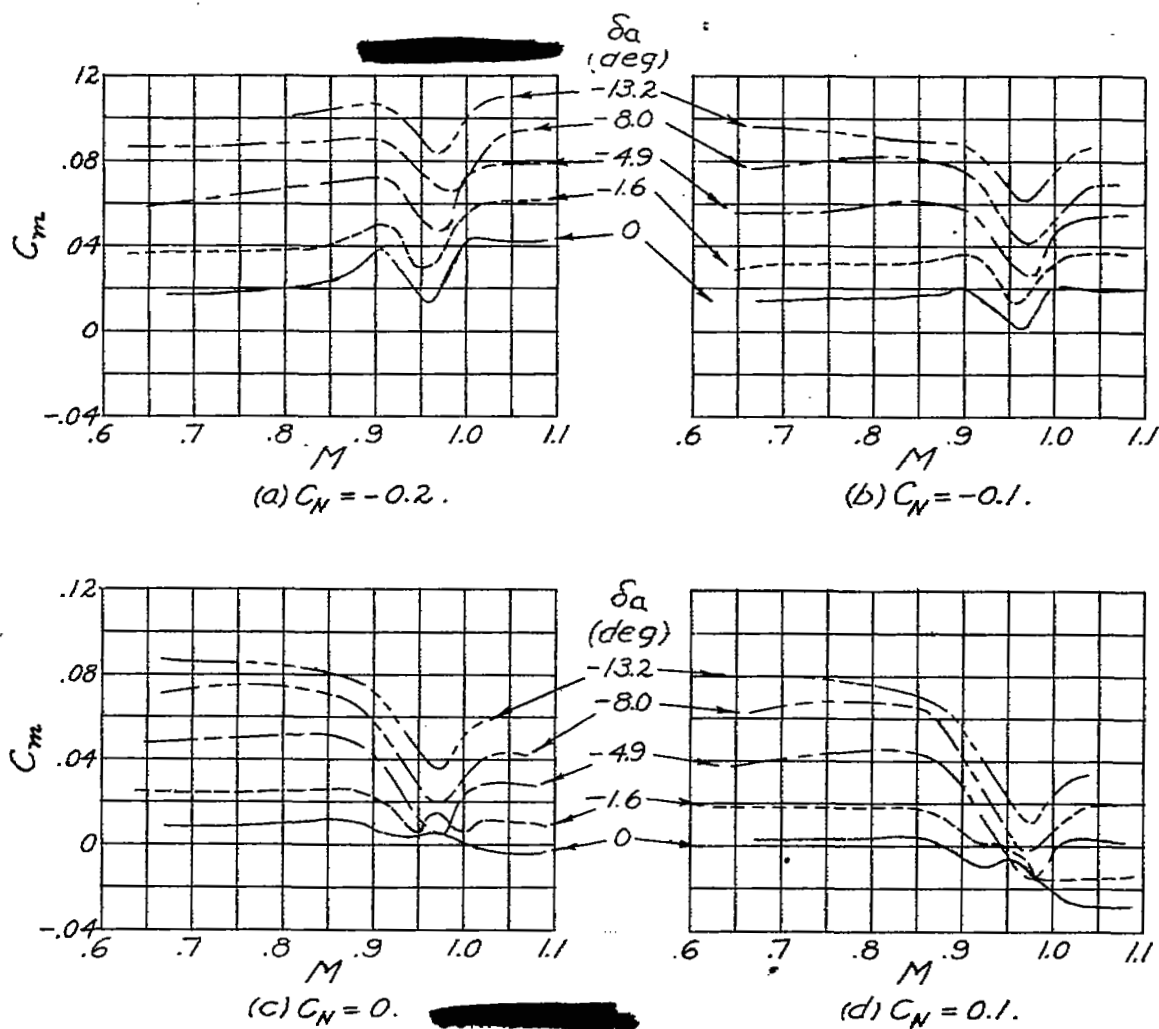


Figure 11.- Variation with Mach number of slope of pitching-moment curve $\frac{dC_m}{dC_N}$ for several ailerator deflections. Normal-force coefficient for level flight also shown.



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Figure 12.- Variation with Mach number of pitching-moment coefficient for various aileron deflections at several normal-force coefficients.

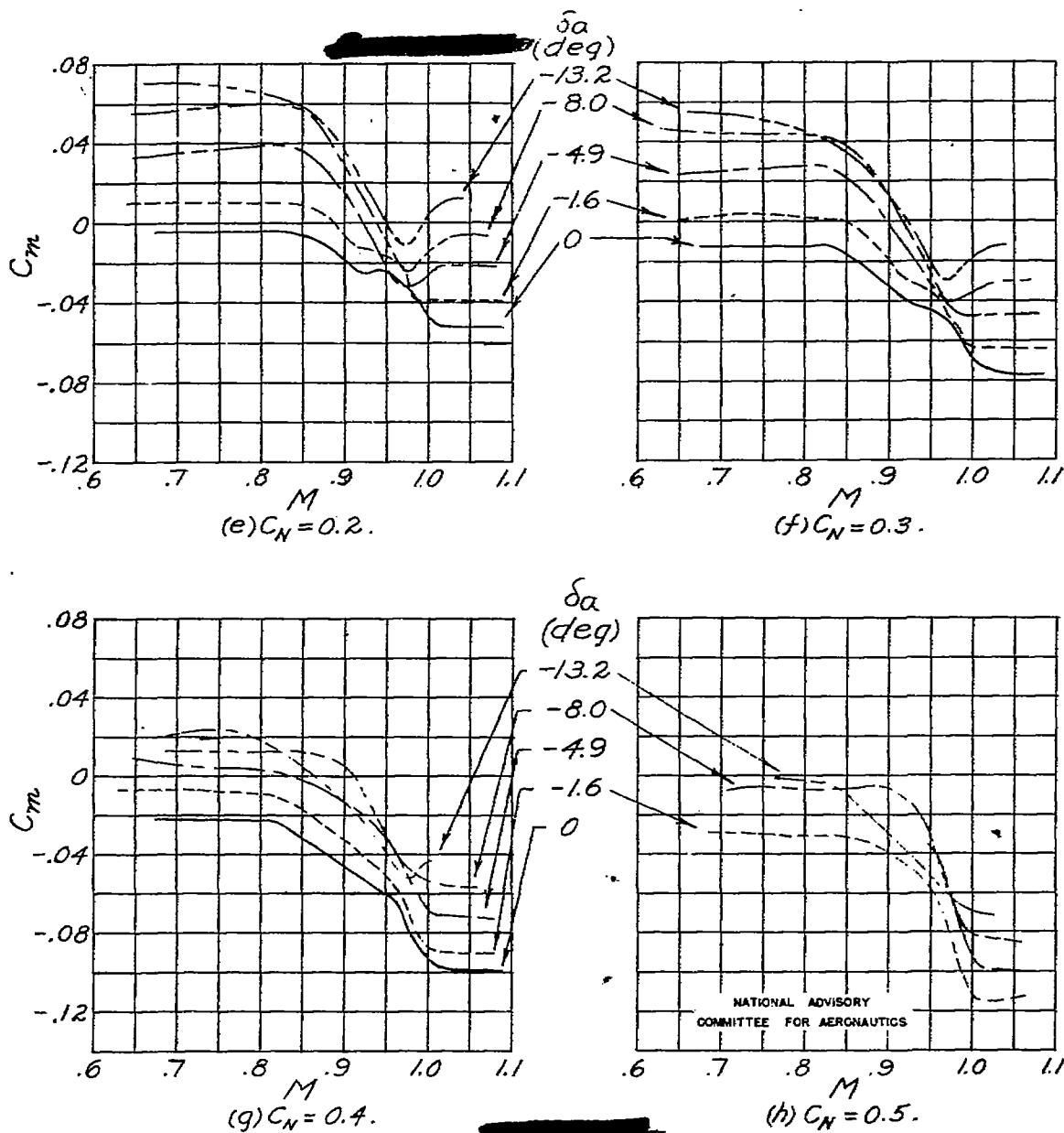


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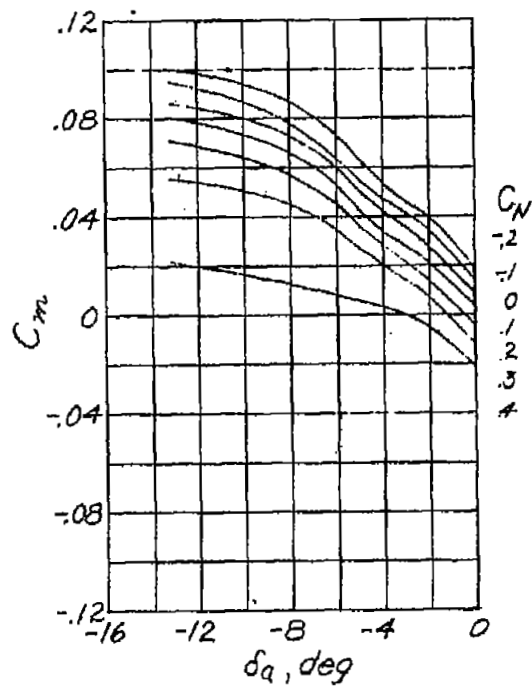
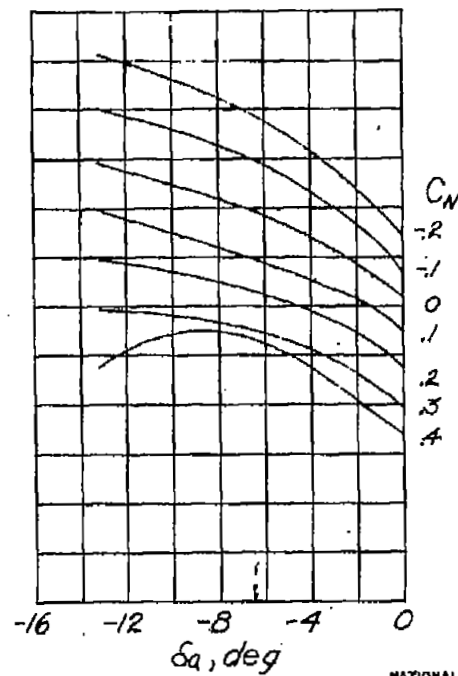
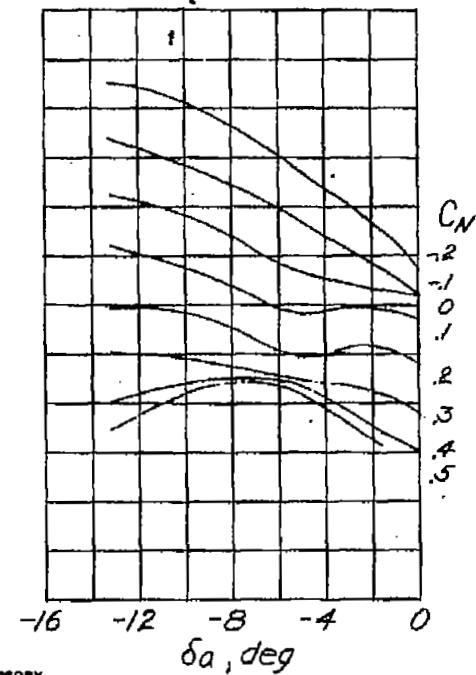
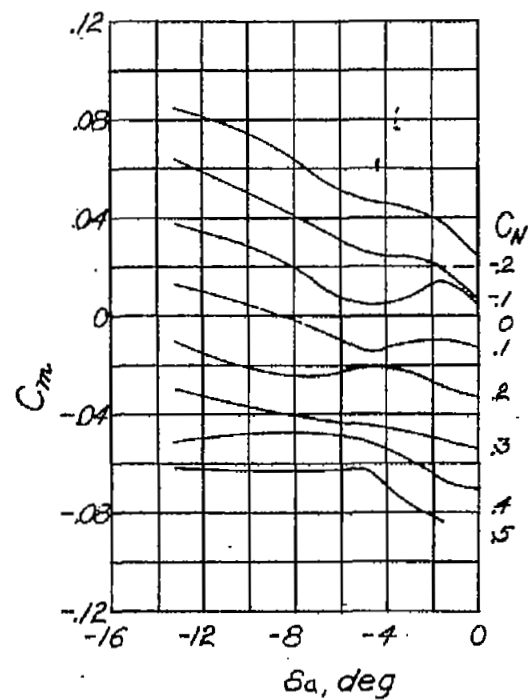
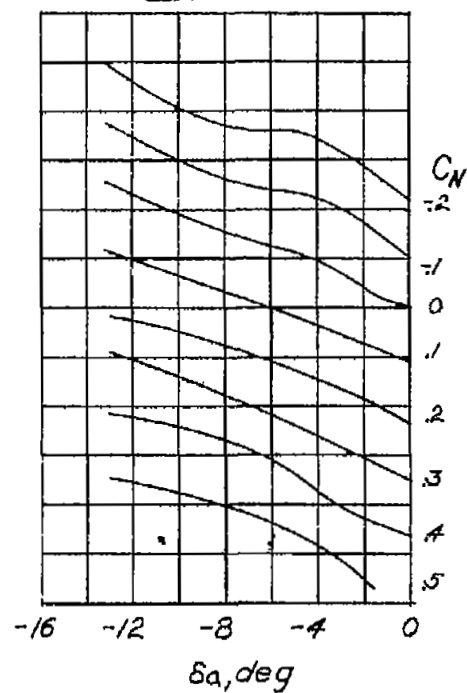
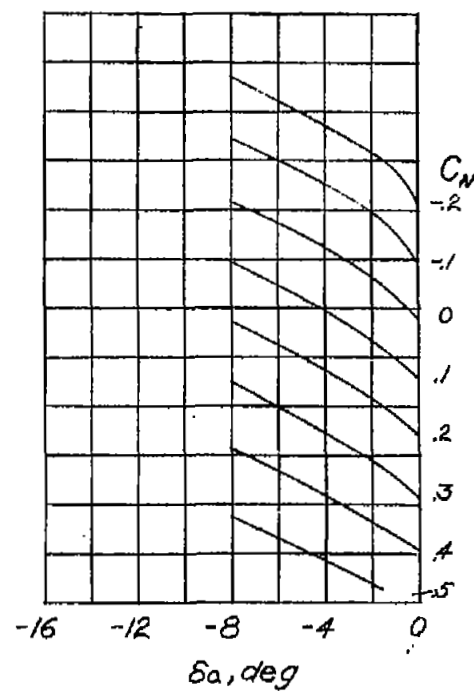
(a) $M = 0.70$.(b) $M = 0.925$.(c) $M = 0.95$.NATIONAL ADVISORY
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Figure 13.- Variation of pitching-moment coefficient with ailerator deflection for several normal-force coefficients at various Mach numbers.

(d) $M=0.975$.(e) $M=1.00$.(f) $M=1.05$.

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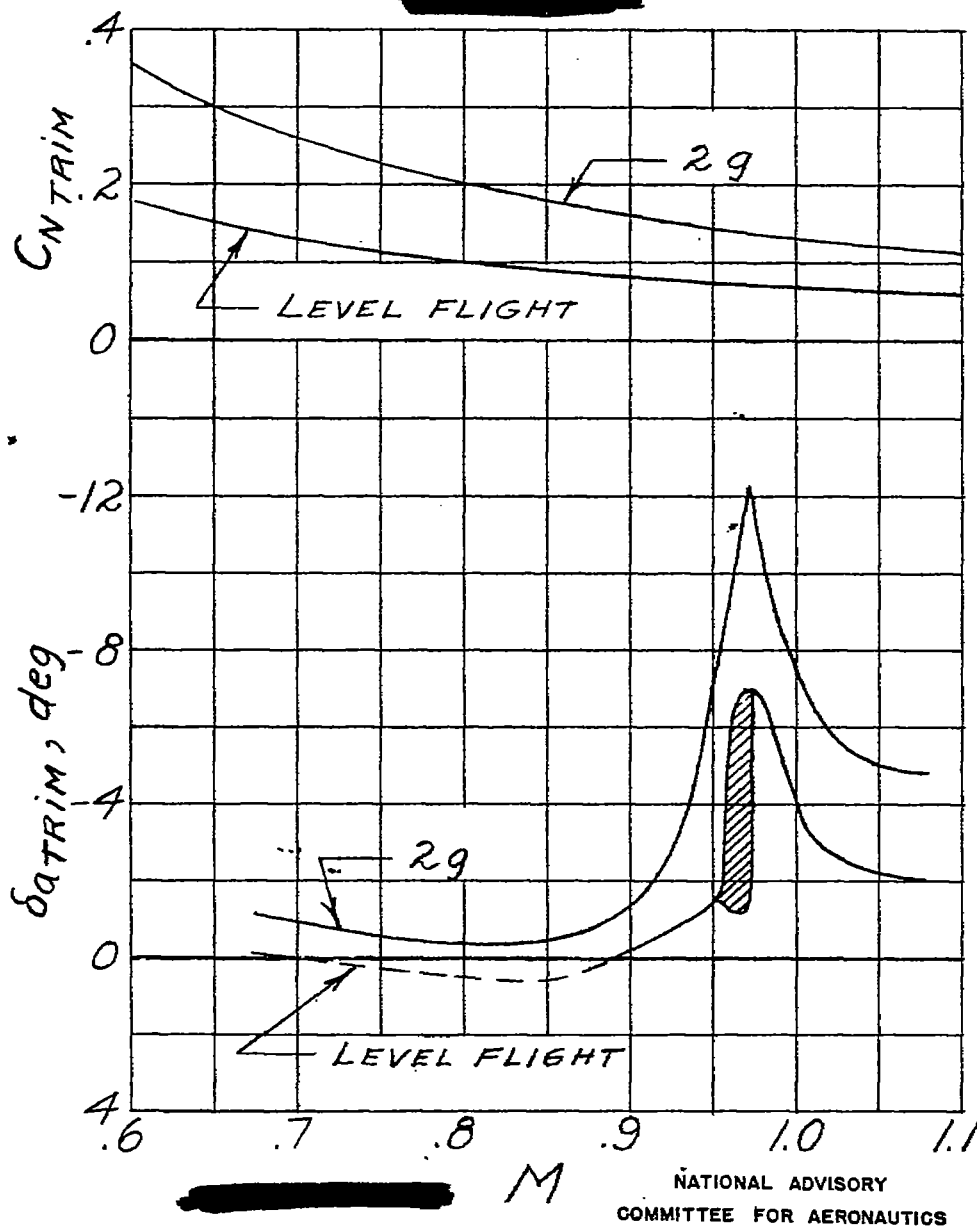


Figure 14.- Variation with Mach number of ailerator angle required for trim in level and 2g accelerated flight at altitude of 30,000 feet with wing loading of 28 and center of gravity at 17 percent M.A.C. Normal-force coefficient for level and 2g accelerated flight also shown.